Econometrics 1st Assignment

Submitted by
Fabio Fortis, Nikolas Aschenbrenner, Mridul Jain

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Table of Contents

1 Summary

This analysis examines factors influencing firms' debt ratios, highlighting industry differences, statistical outliers, and key drivers like firm size, market valuation, and risk. Capital-intensive industries show higher leverage, while asset-light sectors rely on internal funding. Multivariate regression identifies sales, profitability, and firm-level risk as the strongest predictors of leverage, with an optimized model explaining 84.79% of debt ratio variation.

2 Dependent variable

The computed debt ratios, based on the market value of equity and the book value of debt, reveal distinct industry patterns. High-leverage industries include financial services, utilities, and automobiles. Financial firms like Deutsche Bank (0.9888) and Allianz (0.9201) exhibit the highest debt ratios, reflecting reliance on borrowing and regulatory capital needs. Utilities such as RWE (0.8617) and E.ON (0.7111) maintain high leverage due to significant infrastructure investments and stable cash flows. Automakers like Volkswagen (0.8449) and Daimler (0.8143) also rely on debt for capital-intensive operations and financing R&D.

In contrast, industries with lower capital intensity, such as technology, consumer goods, and healthcare, show lower debt ratios. Technology firms like Infineon (0.1778) and SAP (0.1789) rely on intellectual property and minimal physical assets. Consumer goods companies, including Beiersdorf (0.1379) and Adidas (0.2008), leverage strong cash flows to minimize debt, while healthcare firms like Merck (0.3402) and Fresenius (0.4345) benefit from stable earnings and cash reserves. These patterns demonstrate how capital-intensive industries rely more on debt to finance large fixed assets, while asset-light industries use strong cash generation and lower capital needs to maintain minimal leverage.

3 Descriptive statistics

Outliers across multiple variables in the dataset significantly impact statistical analysis. To identify these outliers, boxplots were created for each variable. The middle line of each boxplot represents the median, while the box encompasses the 10th to 90th percentiles, with whiskers extending the 90^{th} and 10^{th} percentiles by 1.5 times the interquartile range (IQR). Values falling outside these whiskers are classified as outliers.

For the variable Book Debt, outliers include Allianz SE with a value of 863.773 and Deutsche Bank AG with a value of 1.284.075. Similarly, in Book Assets, the outliers are Allianz SE at

927.452 and Deutsche Bank AG at 1.348.137. In terms of Sales, Volkswagen AG stands out with a value of 235.849.

These outliers distort statistical measures like means and standard deviations, influencing interpretations of the dataset. Robust techniques such as winsorization, logarithmic transformations, or excluding extreme values may be necessary to address these impacts and ensure a more reliable and representative analysis.

4 Univariate analysis

4a)

The relationship between the book value of assets and the debt ratio highlights how firm size influences leverage decisions. Firms with larger book values of assets generally exhibit lower debt ratios, as these firms, such as Allianz, Daimler, and Volkswagen, are less reliant on debt due to greater internal capital generation, higher creditworthiness, and access to equity markets. Conversely, smaller firms, such as Wirecard and Beiersdorf, often rely more heavily on debt, leading to higher debt ratios. This pattern underscores the economies of scale, where larger firms enjoy financial advantages that reduce their dependence on leverage.

To further refine the analysis, the logarithm of the book value of assets is often used. Logarithmic transformation smooths variability among firms of different sizes, capturing proportional differences in asset size and mitigating the effects of outliers. This transformed variable exhibits a stronger negative correlation with the debt ratio and provides greater explanatory power. Econometric analysis confirms this: in regressions using the debt ratio as the dependent variable, the R-squared for the book value of assets is 0.350, thereby explaining 35% of the variation in the debt ratio. In contrast, the R-squared for the logarithm of the book value of assets is 0.643, explaining 64.3% of the variation. Thus, the logarithmic transformation better normalizes the data and reduces variance instability, or heteroscedasticity.

Economically, this pattern is explained by the differences in financing strategies and market access between larger and smaller firms. Larger firms benefit from better credit ratings, more stable cash flows, and cheaper equity, allowing them to maintain lower leverage. In contrast, smaller firms face higher volatility in earnings, limited internal funding, and weaker market positions, leading to a higher reliance on debt. Sectoral characteristics also play a role, as capital-intensive industries like automotive and utilities naturally exhibit higher leverage levels. Firms such as BMW, Daimler, and RWE reflect this trend.

Overall, the logarithmic transformation of the book value of assets better explains the debt ratio due to its ability to normalize firm size differences and highlight the proportional relationship between assets and leverage. This negative relationship reflects the financial economies of scale enjoyed by larger firms, reducing their dependence on debt financing.

4b)

The relationship between Tobin's Q and the debt ratio provides insights into how market valuations and leverage interact in determining a firm's capital structure. Tobin's Q, defined as the ratio of the market value of total assets to their book value, serves as a market-to-book ratio reflecting investor confidence and growth potential. An analysis of the relationship reveals significant findings, supported by a regression where Tobin’s Q is the independent variable and the debt ratio is the dependent variable. The regression results show an R-squared of 0.786, indicating that 78.6% of the variation in the debt ratio is explained by Tobin’s Q. This high explanatory power arises from the overlap in their calculation, as both metrics include variables such as book debt and market capitalization.

Economically, this relationship can be interpreted in multiple ways. On one hand, leverage can positively influence Tobin's Q when debt is used to finance projects with returns exceeding their cost of capital. This boosts profits and market valuation, enabling growth and potentially signaling efficient capital allocation. On the other hand, excessive leverage increases financial distress risk, which erodes investor confidence and depresses market value, leading to lower Tobin's Q. Firms with high debt ratios may also face inefficiencies or vulnerabilities during economic downturns, further reducing their valuation.

Empirical observations from the dataset illustrate these dynamics. Firms like Deutsche Bank and Lufthansa, with high debt ratios (>0.75), exhibit relatively low Tobin’s Q values (close to 1), likely due to investor concerns about financial stability. In contrast, firms such as Adidas and Beiersdorf, with low debt ratios (<0.25), show high Tobin’s Q values (>20), reflecting strong market reputations and the presence of intangible assets that elevate valuations. Mixed cases, such as Bayer, with moderate debt ratios (~0.6) but lower Tobin's Q (~10), suggest challenges in leveraging debt effectively or market skepticism about future returns.

Visual analysis further supports these patterns. A scatter plot with a regression line indicates an inverse relationship: firms with high Tobin's Q cluster at lower debt ratios, while those with low Q values tend to have higher debt ratios. This trend aligns with the economic theory of an optimal capital structure, where firms balance the benefits of debt, such as the tax shield, against its costs, including financial distress and market risks. At this optimal point, Tobin’s Q might be maximized, reflecting efficient leverage and strong market valuation.

4c)

The relationship between the debt ratio and risk measures reveals key insights into how leverage interacts with equity and firm-level risks. For equity risk measures, such as equity volatility (σE) and equity beta (βE), the results show weak or negligible explanatory power. The R-squared values for these measures are 0.033 and 0.019, respectively, with negative adjusted R-squared values, indicating almost no correlation. This suggests that the debt ratio is not significantly influenced by equity risk metrics in this dataset. Potential explanations include the possibility that firms in the sample have diverse leverage policies that are independent of their market risk characteristics, or that equity risk measures are shaped more by operational or external market factors than by financial leverage.

In contrast, firm-level risk measures, including firm volatility (σV) and firm beta (βV), show much stronger explanatory power. The R-squared values for firm-level volatility and beta are 0.741 and 0.716, respectively, highlighting a significant relationship. This can be partly attributed to the mathematical structure of these measures, as the debt ratio is embedded within the formula for calculating firm-level risk measures. Economically, this reflects the idea that firm-level risk measures are more tailored to individual firm characteristics, capturing specific financial and operational factors that directly influence leverage decisions.

From an economic perspective, high leverage reduces firm-level risk metrics (σV and βV) because debt holders absorb a portion of the firm's risk. Conversely, low leverage increases firm-level risk, reflecting higher sensitivity to market fluctuations. These findings align with capital structure theories, where the interplay between risk management and investor preferences shapes leverage decisions. While equity risk measures provide limited insights in this context, firm-level metrics offer a more precise and comprehensive understanding of the relationship between risk and leverage.

4d)

The analysis of additional variables and their relationship with the debt ratio provides further insights into the factors influencing a firm's leverage. Six regressions were conducted, each using one of the remaining variables—1-year return, book equity, sales, EBITDA, EBIT, and net income—as the independent variable and the debt ratio as the dependent variable. These variables were chosen as they are not directly used in the calculation of the debt ratio, allowing for an independent assessment of their explanatory power.

Among these variables, the 1-year return exhibits the lowest explanatory power, with an R-squared of 0.029 and a negative Adjusted R-squared of –0.006. This indicates that the 1-year return has virtually no meaningful relationship with the debt ratio in this dataset. The weak correlation could be attributed to the fact that short-term market performance metrics, such as the 1-year return, are more reflective of market conditions and investor sentiment than of long-term financial structure or leverage decisions.

In contrast, the variable "Sales" shows the highest explanatory power, with an R-squared of 0.210 and an Adjusted R-squared of 0.182. This suggests that sales, as a measure of operational size and revenue-generating capacity, have a stronger connection to leverage decisions. Economically, this relationship makes sense as firms with higher sales often have greater capacity to service debt, making them more attractive to creditors. Moreover, sales reflect a firm's operational scale, which may influence its ability to balance leverage against financial risk. The other variables—book equity, EBITDA, EBIT, and net income—fall between these extremes, each showing varying degrees of explanatory power. These findings highlight the varying importance of operational and performance-related metrics in understanding a firm's capital structure, with sales emerging as a key driver of the debt ratio in this analysis.

5 Multivariate analysis

The multivariate analysis involved running regressions with multiple independent variables to identify the model with the best fit for explaining the variation in the debt ratio. Generally, one can assume that a model with more variables will be able to explain more of the variation in the debt ratio. After testing various combinations, the optimal model includes all variables except for the 1-year return. This model achieves an Adjusted R-squared of 0.8479, indicating that it explains 84.79% of the variation in the debt ratio.

The exclusion of the 1-year return is consistent with earlier findings that it has the lowest explanatory power among the tested variables and more importantly, a negative Adjusted R-squared. Thereby, the addition of the 1-year return makes the model worse. By removing this variable, the model eliminates noise and focuses on more impactful predictors, such as sales, book equity, and profitability metrics like EBITDA, EBIT, and net income. The high Adjusted R-squared highlights the combined strength of these variables in capturing the drivers of leverage decisions, reflecting the interplay of operational size, financial performance, and market valuations in determining a firm’s capital structure.

6 Table with descriptive Statistics

Table 1: Descriptive Statistics

	Min	10th Quantile	Median	Mean	90th Quantile	Max	S.D.
Market cap	8,331.110	11,551.760	26,253.590	36,481.420	70,737.850	103,789.900	25,456.260
1yr Return	-0.558	-0.404	-0.146	-0.153	0.114	0.431	0.239
Volatility	0.161	0.179	0.223	0.254	0.329	0.455	0.071
Beta	0.502	0.627	0.986	0.991	1.360	1.699	0.286
Book Debt	3,307	5,777.500	33,992.500	136,448.600	259,396.100	1,284,075	274,297.500
Book equity	1,923	5,333.800	17,783	28,272.270	63,717.300	104,746	25,173.410
Sales	2,016.200	6,822.940	31,547.500	46,142.430	98,270.200	235,849	51,368.270
EBITDA	560.800	1,344.400	4,681.550	7,972.833	20,515.400	38,685	8,743.359
EBIT	229	995.180	3,398.600	4,567	10,224.500	17,190	3,884.460
Net income	8	346.160	2,119	2,879.681	7,130.200	11,827	2,698.993
Debt Ratio	0.138	0.193	0.587	0.566	0.891	0.989	0.254
Book Assets	5,875	11,259.600	53,485.500	164,720.900	301,876.500	1,348,137	289,451.800
log(Book Assets)	8.678	9.329	10.887	11.122	12.603	14.114	1.311
Tobin's Q	0.011	0.118	0.444	0.740	2.045	2.793	0.771

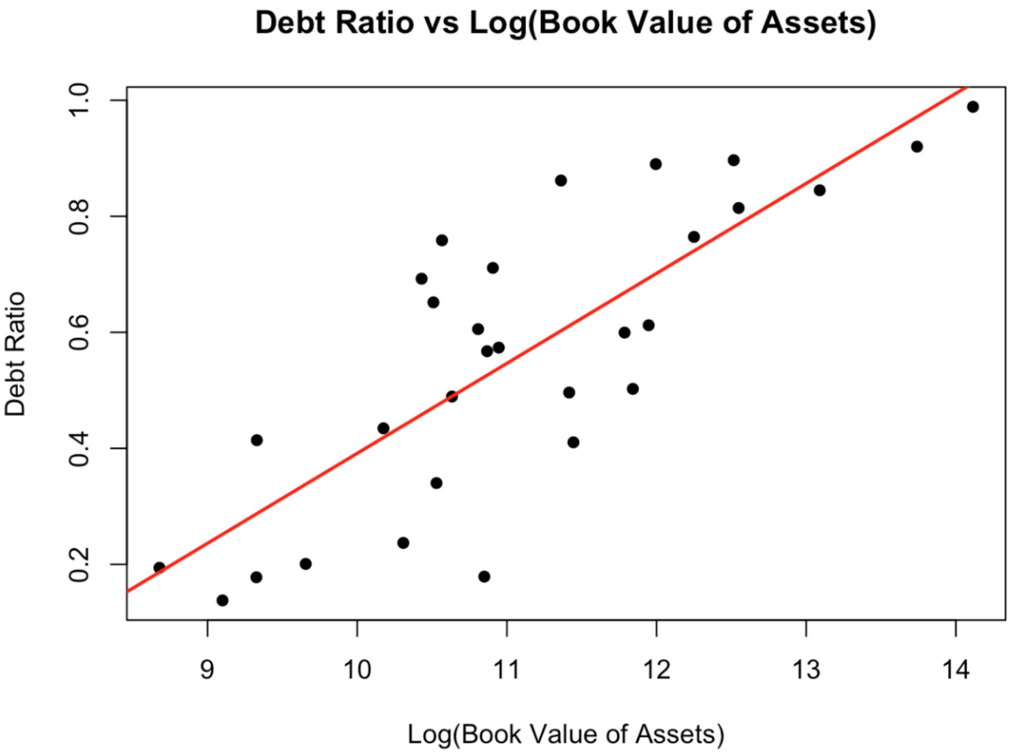
Notes: This table presents the minima, 10th percentiles, means, medians, 90th percentiles, maxima and standard deviations of all the necessary variables. The variables "Market Cap", "Book Debt", "Book Equity", "Sales", "EBITDA", "EBIT", "Net Income" and "Book Assets" are given in units of 10,000,000.

Table 2: Number of Observations & Firms

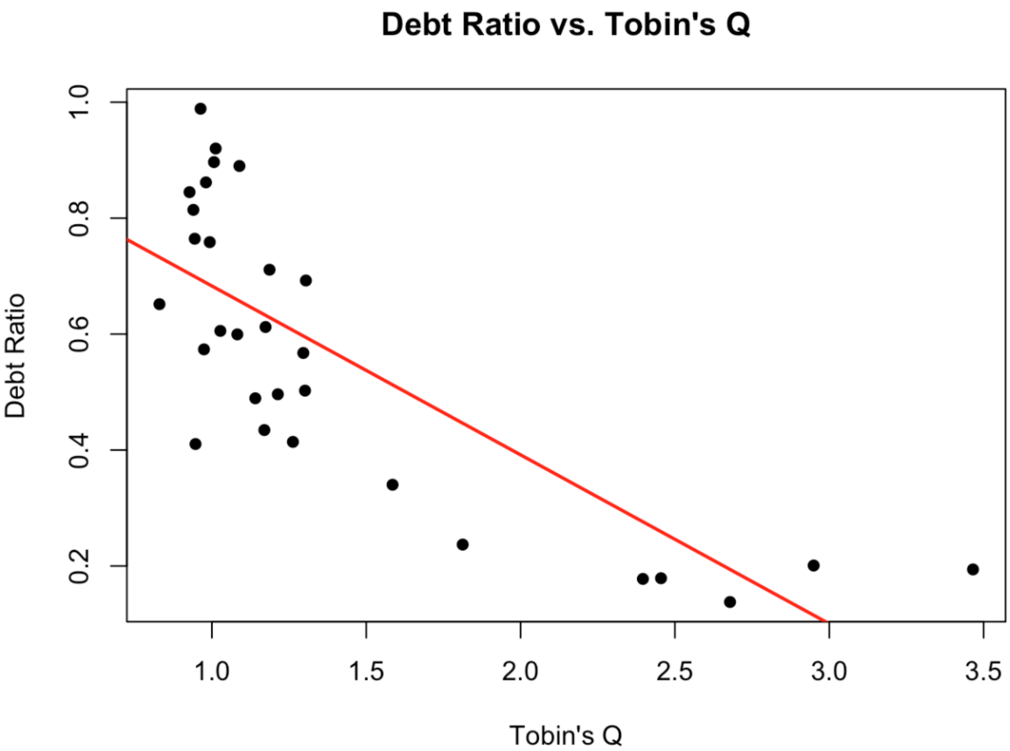
	No. Observations	No. Firms
Market cap	30	30
1yr return	30	30
Volatility	30	30
Beta	30	30
Book Debt	30	30
Book equity	30	30
Sales	30	30
EBITDA	30	30
EBIT	30	30
Net Income	30	30
Debt Ratio	30	30
Book Assets	30	30
log(Book Assets)	30	30
Tobin's Q	30	30

7 Scatter Plots

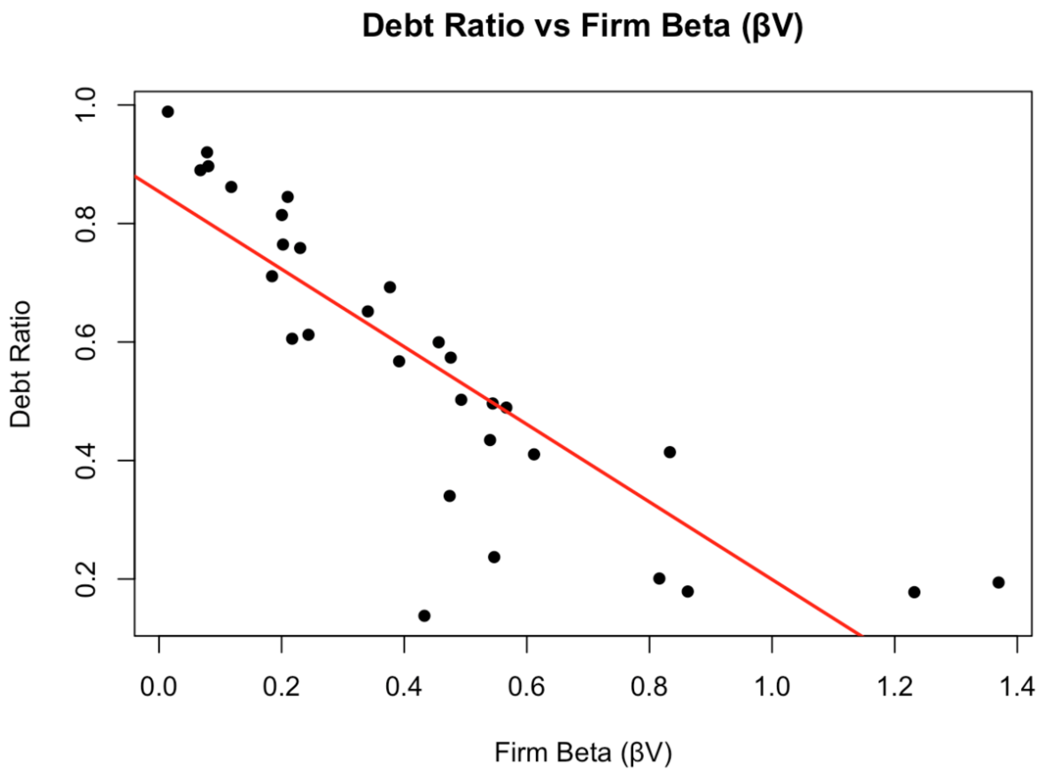
5a) Scatter Plot 1



5b) Scatter Plot 2



5c) Scatter Plot 3


Debt Ratio vs Firm Beta (βV)
Debt Ratio
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Firm Beta (βV)

8 Tables with results of simple regressions

Table 3: Regressions 1-7

	Dependent variable:						
	debtratio						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Book Assets	0.00000***						
	(0.00000)						
log(Book Assets)		0.155***					
		(0.022)					
Tobin's Q			−0.291***				
			(0.044)				
Volatility				−0.644			
				(0.661)			
Beta					−0.123		
					(0.166)		
vvol						−2.655***	
						(0.297)	
vbeta							−0.655***
							(0.078)
Constant	0.480***	−1.160***	0.975***	0.729***	0.687***	0.867***	0.854***
	(0.044)	(0.244)	(0.068)	(0.174)	(0.171)	(0.041)	(0.043)
Observations	30	30	30	30	30	30	30
R^2	0.350	0.643	0.612	0.033	0.019	0.741	0.716
Adjusted R^2	0.327	0.630	0.598	−0.002	−0.016	0.731	0.705
Residual Std. Error (df = 28)	0.208	0.154	0.161	0.254	0.256	0.131	0.138
F Statistic (df = 1; 28)	15.078***	50.476***	44.111***	0.951	0.545	79.993***	70.461***
Note:					*p<0.1; **p<0.05; ***p<0.01		

Table 4: Regressions 8-13

	Dependent variable:					
	debtratio					
	(8)	(9)	(10)	(11)	(12)	(13)
1yr Return	−0.180					
	(0.198)					
Book Equity		0.00000**				
		(0.00000)				
Sales			0.00000**			
			(0.00000)			
EBITDA				0.00001**		
				(0.00001)		
EBIT					0.00002*	
					(0.00001)	
Net income						0.00003
						(0.00002)
Constant	0.538***	0.437***	0.461***	0.477***	0.460***	0.489***
	(0.055)	(0.064)	(0.057)	(0.059)	(0.069)	(0.067)
Observations	30	30	30	30	30	30
R^2	0.029	0.205	0.210	0.147	0.126	0.081
Adjusted R^2	−0.006	0.177	0.182	0.116	0.094	0.048
Residual Std. Error (df = 28)	0.254	0.230	0.229	0.238	0.241	0.247
F Statistic (df = 1; 28)	0.827	7.231**	7.461**	4.821**	4.024*	2.454
Note:				*p<0.1; **p<0.05; ***p<0.01		

9 Table with results of multiple regressions

Table 5: Multivariate Analysis: Regressions 1&2

	Dependent variable:	
	debtratio	
	(1)	(2)
log(Book Assets)	0.190***	0.176***
	(0.048)	(0.053)
Tobin's Q	−0.132***	−0.154**
	(0.044)	(0.055)
vvol	1.479	1.199
	(1.179)	(1.266)
vbeta	−0.355	−0.283
	(0.244)	(0.270)
1yr Return		0.081
		(0.121)
Book equity	−0.00001**	−0.00001**
	(0.00000)	(0.00000)
Sales	0.00000*	0.00000*
	(0.00000)	(0.00000)
EBITDA	0.00001	0.00000
	(0.00001)	(0.00001)
EBIT	−0.00005	−0.00003
	(0.00003)	(0.00004)
Net income	0.00002	0.00001
	(0.00003)	(0.00003)
Constant	−1.220**	−1.035
	(0.539)	(0.612)
Observations	30	30
R^2	0.895	0.898
Adjusted R^2	0.848	0.844
Residual Std. Error	0.099 (df = 20)	0.100 (df = 19)
F Statistic	18.968*** (df = 9; 20)	16.648*** (df = 10; 19)
Note:		*p<0.1; **p<0.05; ***p<0.01

10 Sources & Packages used for the Code

1. expss
2. tidyverse
3. xtable
4. stargazer
5. maditr